MANAV RACHNA INTERNATIONAL UNIVERSITY

Short Synopsis

For

Ph. D. Programme 2014-15

DESIGN FOR OPTIMIZATION OF BIOGAS BASED ENERGY SYSTEMS

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

FACULTY OF ENGINEERING & TECHNOLOGY

Submitted by:

Name: Neena Ahuja
Signature:
Registration No.:14/PHD/010
Email ID:nina_ahuja@rediffmail.com
Contact No.: 9650581155

Supervisor :

Name: Dr. Dipali Bansal
Signature:
Designation: H.O.D , ECE
Email ID: dipali.fet@mriu.edu.in
Contact No.:9910122000

FACULTY OF ENGINEERING & TECHNOLOGY

Declaration

This is to declare that this short synopsis reflects the research work design and its contents are the original piece of work, as per guidelines, grammatically correct and free from plagiarism. This has been prepared under the guidance and supervision of my supervisor/joint-supervisor.

(Signature of Research Scholar)

Name : **Neena Ahuja**
Registration No. : **14/PHD/010**
Batch : **2014**
Department : **EEE**

Certificate

This is to testify that the entire text of this Synopsis, prepared by my research scholar, has been read thoroughly and it is as per the guidelines and grammatically correct. Further, it is original piece of his/her work and free from plagiarism.

Signature of the supervisor
Name :Dr. Dipali Bansal
Designation :HOD
Department :ECE

Recommendation

I recommend this short synopsis prepared and submitted by Ms. Neena Ahuja for approval of Ph.D Quality Enforcement Committee and thereafter to be uploaded on Shodh Gangotri.

Prof. (Dr.) Krishna Kant
Executive Director & Dean, FET, MRIU

Executive Director & Dean
Faculty of Engineering & Technology
Manav Rachna International University
Faridabad, Haryana

ABSTRACT

This research aims at analyzing every step in the process of energy conversion for cooking as well as for electric power generation from the organic fraction of kitchen waste using biomass anaerobic digestion process so that the energy production system could be optimized and existing designs improvised. Researchers worldwide are focused to address the issues pertaining to biomass/organic waste to energy process on the industrial scale that produce power in the megawatt range. Small scale systems as that on the community scale or on the household scale have not received much attention. Complex methods of improvising upon the issues faced by the systems like addition of chemicals and new technology that is capital intensive on the smaller scale and requires expert guidance is being researched on. This thesis shall focus on the performance improvement of the neglected small scale energy production system from biomass/organic waste so that it becomes economically feasible and easily executable for adoption on a mass scale. The objectives shall therefore be to improvise upon each step ranging from selection of the best combination of feedstock using soft computing techniques to eliminate need of an expert advisor and C/N tables that are difficult for a layman to comprehend, compacting biogas digesters for less space occupancy for adaptability in city environment , designing simple mixing systems for enhanced biogas formation , introducing design changes in electric plant layout for minimal space occupancy and increased biogas production, estimating the time interval for introduction of exhaust gas into the digester for temperature control to enable the flourishment of microbial population within the digester throughout the year, selecting the appropriate equipments including the required machinery for engineering the system , preparing the piping and instrumentation diagrams and analyzing the economic parameters for determining the economic feasibility of the combined heat and power system.

A Fuzzy Inference System shall be designed in MATLAB Software that shall enable the layman to select or prepare the best C/N feed combination with over 55% methane potential ; the results of which shall be inferred directly from the Output Surface Viewer or from the Rule Inference Window of the system. Single stage, multistage and other commercial digesters implemented worldwide shall be analyzed so as to design the best possible configuration of digester for lesser space utilization. An agitation system shall be designed and a prototype shall be attempted that would well serve the purpose of providing cooking gas for city kitchens occupying smaller space at the same time providing mobility to the biogas digester. Charts and electric plant layout shall be designed based on the concept of utilization of exhaust gas energy from Internal Combustion engine coupled to generator set or from the cooling water system of the generator to maintain the requisite digester temperature for handy information. Detailed piping and instrumentation diagram, layout and block diagram of a biogas based 800kWh electric power plant shall be designed and its economic feasibility study shall be carried out to determine its implementation success on technical as well as economic grounds. The exercise expects to provide a compact and efficient Biogas based cooking system and power system design that shall be well suited to city structure and shall act as a dustbin for organic waste that is otherwise lying on roads posing a challenge to the Municipal Corporations to be disposed off. It also expects to provide a new dimension to agitating the digester that shall provide a breakthrough in adoption of biogas digesters as energy system in every household. The thesis however does not cover the implementation and the integration of the electricity generation system to the grid which can be attempted in future.

Keywords: Biogas, Fuzzy Inference System, optimize, agitation system, design, compact

CONTENTS

S. No.	Description	Page No.
1	**Introduction** 1.1 World Scenario 1.2 Microgrid in India 1.3 Distributed Generation –Back bone of Smart grid 1.4Organic MSW waste - Solution to intermittent power supply from solar and wind	1 - 6
2	Literature Review	6 – 13
3	Description of Broad Area/Topic	13-15
4.	Problem Identification/Objective of the Study	16
5	Methodology to be adopted	17 – 18
6	Proposed/expected outcome of the research	18
7	Proposed Time Frame (Gantt Chart)	19
8	References	20-23

1. Introduction

Change is the only consistent thing in the world. Distribution grids are being transformed from passive to active networks so that distributed control is encouraged and bidirectional power flow adopted. Distributed control encourages the adoption of Renewable Energy Resources close to the load centre reducing demand for long transmission and distribution lines consequently curbing losses [13]. Real time load and generation matching is the focus area of private power companies the world over necessitating the birth of the concept of microgrids.

Micro grids comprise low voltage distribution systems with distributed energy resources together with storage devices and controllable loads [Fig.1]. These systems are interconnected to the medium voltage distribution network but can also be operated isolated from the main grid or can ride through between these two modes. Smart local micro grids built on the backbone of the existing grid shall act as the building blocks of the much talked about Smart Grids of the future that are visualized to be transmitting power at intercontinental distances [11].

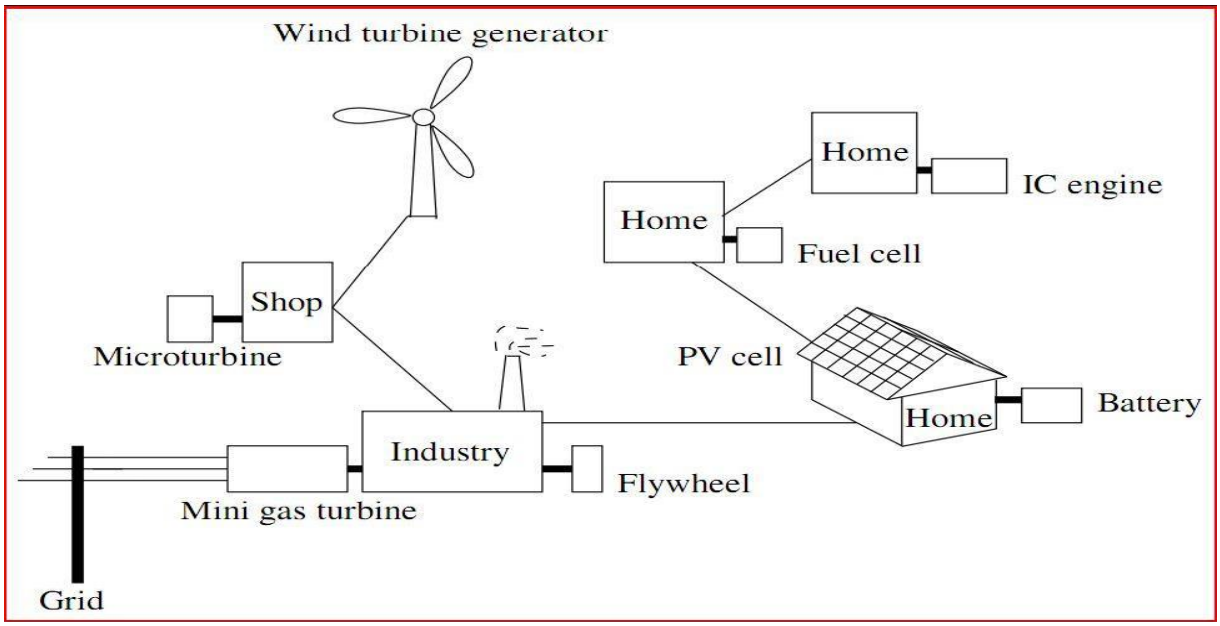


Fig.1: Architecture and Components of a Microgrid

1.1 World Scenario

The Smart Grid technology is being researched in many countries. Projects are underway in Germany 'MEREGIO' (Minimum Emissions Region) being its first Smart Grid project. It is focused on the development of minimum emission certificate for the model region Karlsruhe/Stuttgart in Germany. The project aims at complete elimination of CO_2

caused due to heating and electrical power consumption. It combines conventional power plants, distributed combined heat and power plants, distributed energy storage systems as well as renewable energy systems like wind energy and photovoltaic systems at both the system and customer levels [12]. The Netherlands, Switzerland, Turkey, Wallonia Austria, France, Denmark, Spain, Norway, Greece, Belgium, Croatia, Slovenia, Sweden, Scotland, Romania, Portugal, Poland, Latvia, Germany, Flanders, Finland, and Switzerland have collaborated to develop research activities and funds to speed up the development of a smart European Electrical Infrastructure via the ERA-NET Smart Grid Plus Project [40]. The power sector of Great Britain accounts for 27% of its Green House Gas Emissions which needs to be brought to zero by 2050 and will be accomplished by generation from renewable energy, nuclear power, fossil energy with carbon capture and storage [27]. Ministry of Power of India too has stepped into the Smart Grid era with 14 pilot projects to be implemented by state-owned distribution utilities [26].

1.2 Microgrid in India

India plans to empower the 237 million people presently in energy crisis with 10,000 renewable energy micro grids and mini grids. Microgrids as defined by the Ministry of New and Renewable Energy, India is distributed generation based on renewable energy under 10 kW that can be operated standalone or connected to central grid while minigrids operate on systems over 10 kW [46].

Gram Oorja has commissioned a number of solar based microgrid projects in the villages of Darewadi, Jawhar, Songiripada ,Vazarepada , Humranpada , Vanvasipada , Dharni villages of Maharashtra ; Viral, Bhamane of Karnataka ; Gumla of Jharkhand providing them with 24x7 electric energy and eliminating them from darkness as there was no grid connection in these villages [23]. Another micro grid network at Alamprabhu Pathar in Kolhapur District of Maharashtra is based on a combination of energy resources : 2,400 kW through natural gas based generators, 500 kW through biomass based generators and 14,250 kW through Wind Turbo generators to meet the total electric load of the area [2].

Smart Grid can be looked upon as an interconnection of numerous microgrids and mingrids that shall offer the country hope of reducing the transmission, distribution and theft losses that amount to as high as 50 % on an average; planned distribution network with improved reactive power support and voltage regulation ; greater metering efficiency and bill

collection thus boosting revenue collection. Amongst the various renewable energy options available greater focus has been on wind and solar energy although their lacuna of intermittent supply can be resolved by harnessing power from biomass or Municipal Solid Waste (MSW) that is abundantly and always be available till mankind survives [10].

1.3 Distributed Generation –Back bone of Smart grid

The advantage of distributed generation (DG) over centralized generation is the improvement in efficiency of power supplied. Roughly 4.2 – 8.9 % of electricity is lost due to aging of equipments used in transmission lines, inconsistency in following guidelines of reliability, growth of traffic congestion, poor power quality etc. The DG electricity is inexpensive as it does not have to cater to the cost of the vast laid transmission line. Affordable power with better power quality can be obtained by onsite generation system. A further benefit of Distributed Generation is the income one can generate by selling the power to the grid during peak demands. Central Power Stations are one of the biggest contributors to environmental pollution, while distributed generation systems are mainly based on green energy. Distributed Generation can reduce the need for expansion and upgradation of transmission network thereby reducing costs. Distributed Systems help in keeping the power system secure as they are not potential terrorist attack targets unlike centralized power system plants based on nuclear power, thermal power etc. Distributed Generation systems help power essential/emergency services like police stations, hospitals, schools, fire stations, airports, military bases, communication stations etc. [16].

1.4 Organic MSW waste - Solution to intermittent power supply from solar and wind

Non conventional energy resources such as wind, sun light and biomass, have gained important place in the micro grid project schemes the world over. Among the various renewable energy sources, bio-resources of which agro-residue forms a major component hold special promise as future fuel and feedstock. Biomass – based systems are the only energy generating systems, which have the combined benefits of renewability, decentralization, and availability on demand without need for separate storage. Taking into account the energy requirements of collection, processing and conversion to convert forms of that, biomass still assures a bright future from energy point of view.

After coal, oil and natural gas biomass stands fourth as the largest energy resource worldwide [7]. It is available widely all round the year, is inexpensive, is easily transportable

and storable without any environmental hazards. Biomass is a versatile source of energy which can be converted to 'modern' forms such as liquid and gaseous fuels, electricity and process heat. Bio-energy also permits operating at various scales, viz small scale (5-10KW), medium-scale (1-10MW), and large scale (about 50MW) electric power systems or biogas plants ranging from a few cubic meters to several thousand cubic meters [24]. This variety of scales is useful for power generation for decentralized applications at the village/city level as well as for supply to the natural grids.

The September 2017 Report released by the Ministry of Power of The Government of India has confirmed 3, 29,226 MW as the country's total installed electric power generation capacity as on 31 August 2017. Contribution from Private Sector stood at 43.9%, from State Sector at 24.8% and Central Sector at 31.3% of the total installed capacity. Contribution from Thermal Power was 66.7% , Hydro-13.6%, Renewable energy sources including biomass power, urban and industrial waste power , small hydro power , biomass gasifier -17.17% and Nuclear power -2.1% . Electric Power generation Targets set up for the year 2017-2018 stand at 1229.400 Billion Unit (BU) of which 1042.028 BU are from Thermal Power, 141.400 BU are from Hydro power, 40.972 BU are from nuclear power and 5 BU are import from Bhutan. Deficit in available energy stood at 0.7% in the year 2016 -17 against the peak demand deficit of 1.6%. The 2017-18 figures stood at 0.6% and 1.6% deficits in energy availability and peak demand till August 2017 respectively [22]. The Government of India's aim to provide uninterrupted electric power to all its citizens by March 2019 led to the launch of "Power to All" scheme [45][42]. Sixty Indian cities were identified as potential sites for Solar City Project development that would be based on new renewable energy fueled power plants and / or employment of energy efficient techniques in order to reduce a minimum of 10% of the projected electric power demand from conventional energy resources in a span of 5 years. Of the 31 cities sanctioned approval to develop the master plan for Solar City development, the city of Faridabad from Haryana State figures amongst one of them [21]. The physical quantity namely water stream and wind need to flow over a particular speed in the case of small hydro and wind farms for conversion to electric energy. Continuous sunlight availability needs to be ensured to harness electric power which is not feasible in any of the three cases. Distributed power obtained through anaerobic decomposition of organic waste in either stand alone or grid integrated or ride through mode can serve as the best solution to 24x7 electric power supply

availability all year round. Biomass - especially the fruit and vegetable fraction of MSW is a rich hidden energy source mostly untapped and unscientifically disposed due to unavailability of land area and insufficient disposal techniques; the Municipal Corporation of Faridabad (MCF) being a valid example which is insufficiently equipped with only one 1000 tonnes per day MSW treatment plant at Banwari village. Most of the waste from Faridabad especially the Old city still finds dumping ground at Kheri without treatment [35].

The MCF is posed with an increasingly challenging task of disposing the six hundred tonnes of Municipal Solid Waste that is generated daily. The waste comprises of 58% biodegradables , 18% recyclables, 32% inerts, and 19% non- biodegradables. The 58% biodegradable waste has a high potential for conversion to energy through anaerobic digesters. The Resident Welfare Associations (RWA) of Old Faridabad help collect waste for the MCF. The RWA's could play a significant role in tapping this energy by promoting and developing community biogas plants that would provide cooking gas to the society or electricity to its parks [18].

Community based waste to energy power plants or biogas systems installed in an individual's verandah to fuel kitchen or biogas generators offer great hope to the clean, green and sustained maintenance of the city. The hurdle faced in widespread acceptability of biogas plants is attributed to the irregular production of biogas from anaerobic digesters. For continued sustenance of constant methane production a number of parameters need addressing which include the maintenance of C/N ratio of the substrate within a determined range, constant temperature range, pH within the digester, proper agitation of digester contents, Total Solids concentration, the Hydraulic and Solid Retention Time, Type of system - single stage or multistage etc. [19][41][21].

Internationally the above parameters are being controlled automatically/ semiautomatically through sensors in medium to large scale waste to energy plants, however at individual level or community level plants not much guidance is provided to the operators. Shortage of space in city environments poses another challenge to the adoption of the biogas technology to power our homes, cities and parks. A need therefore exists not only to control these parameters but also improve the efficiency of each stage in the Biogas based energy systems. We could then boost of inexpensive electric power supply and kitchen fuel all year round driven through ingredients in our litter boxes enabling the participation of every

individual in the smart grid chain.

2. Literature Review:

The challenge faced in the development and acceptance of Biogas Based technology at individual and community level lies in enhancing the efficiency of every stage of the biomass to biogas conversion process. Biogas production efficiency depends on factors like the C/N (Carbon to Nitrogen) ratio, slurry concentration, digester's pH environment, inoculum, organic loading rate, hydraulic retention time and solid retention time, temperature etc. [19][41][21].

Researchers worldwide have attempted to simulate the effect of some of these parameters using soft computing. Abdallah *et. al.* [1] in 2009 developed a system in fuzzy logic with input variables viz: time, sludge addition and leachate recirculation for anaerobic bioreactor landfills. The rate of generation of Biogas was taken as the output variable. Aydinol *et. al.* [6] in 2010 developed a Fuzzy Logic Model for a 90 litre Up - Flow Anaerobic Sludge Blanket Reactor (UASB) in order to predict biogas and methane production rate for molasses wastewater substrate. The fuzzy model operated on two input volumetric variables of organic loading rate and total chemical oxygen demand removal rate and three other variables viz; influent alkalinity, influent pH and effluent pH. Steffen Patzwahl *et. al.* [37] in 2001 attempted to optimize the anaerobic digestion system using microcontroller based fuzzy system. Continuous gas yield was ensured by regulating the substrate input according to the gas produced. Supply rate of the substrate was decided by 22 numbers of fuzzy rules applied on inlet parameters like gas amount/day, average methane concentration/day, average carbon dioxide concentration/day, average oxygen concentration/day, methane to carbon dioxide concentration ratio/day, difference of gas amount between present and previous day, difference in methane amount between present and previous day and pH value arithmetic mean.

I.J. Dioha *et. al.* [15] in 2013 established that the yield of methane and biogas depends on the substrate fed to it and its Carbon to Nitrogen ratio. The researchers documented that low C/N ratio waste materials yield high ammonia and Volatile Fatty acids resulting in hindrance to the activity of methanogenic bacteria; while very high C/N ratio results in increased CO_2 formation which is invaluable as an energy source. Co-digestion helps in maintaining C/N close to 30 which is considered as an ideal number by biogas industry. Tables are available stating the C/N ratio of various substances to provide guidance to biogas operating personnel to take a call on the proper mix of the matter at their anvil to maintain the C/N ratio close to 30.

This is a tedious task and needs trained personnel. Soft computing would help in providing proper decision on the selection or rejection of such a feedstock as trained and experienced personnel are few and the rate at which technology needs application is quick.

Majid Jamil *et. al*. [32] in 2015 attempted a biogas power plant design for the installation in the backyard of a 1500 m^2 two storey house located in the city of Faridabad, Haryana India to meet the energy requirements of running a 2KWh hot air blower/ air conditioner for eight sleeping hours during night using the vegetable and fruit fraction of Municipal Solid Waste generated in the city. The design however suffered some practical problems: it was voluminous – a 15 m^3 digester for generating around 16 kWhe is large covering a substantial space.

Themburkar *et.al.*[41] in 2008 experimented on the hydrolysis and the acidogenesis phases of kitchen waste under completely submerged conditions. Five experiments were run in five litre reactors at total solid concentrations of 2%, 3%, 5%, 7% and 9% with pH maintained between 5 and 6. The acidification efficiency improved by 15.58% during the initial four days of the hydrolysis – acidification process and appeared to be stagnating henceforth. The solubilisation rate was observed highest between 3-5% solid to liquid ratio over which it decreased due to decrease in pH. Observations recorded that solubilisation rate stands highest in the 3-5% solid to liquid ratio range; pH ranging within the 5- 6 range, Total Solid Concentration in the influent between 3-5%, 5 day hydrolysis and acidogenesis combined phase, every 3 hours occasional mixing and addition of inoculum (5%v/v). Gas yield during the hydrolysis phase increased at a fast rate till day 5 reaching 40%; thereafter slow rate improvement was noticed which stagnated by day nine.

Mohan *et. al.*[33] in 2008 studied anaerobic digestion of kitchen in two separate set ups : first being the single stage digestion process wherein only one digester was used and the other being the two stage process wherein the anaerobic digestion was carried out first in a separate hydrolysis chamber and then in a separate methanogenic chamber. The Single stage anaerobic process was operated for a retention time of 15 days within the organic loading range of 1.5 kg VS/m^3 - day to 5.5 kg VS/m^3 – day. On the pollutant removal and biogas production scale an organic loading rate of 4.5 kg VS/m^3 – day recorded a higher efficiency. Again the demand of Chemical Oxygen and the destruction of Volatile Solid was observed as 81% and 79% respectively. Methane production was recorded as 0.288 m^3 per kg of volatile solids added.

The two stage process was subjected to loading rates of 4 kg, 6 kg and 8 kg of Volatile Solids per m^3 – day. For a total retention time of 10 days; 5 days each for the hydrolysis and the methanogenesis stages. The removal efficiency of chemical oxygen demand was recorded at a whopping 92% and the destruction of volatile acids was recorded a high at 94% at an Organic Loading rate of 8Kg VS/m^3 - day. The experiment recorded 0.22 m^3 of methane production/kg VS added. It was concluded that the two stage systems exhibited better tolerance to fluctuations in organic loading rate and higher methane production as compared to single stage systems.

The Biotechnische Abfallverwertung GmbH & Co. KG (BTA) [9] System Literature highlights the two stage systems to be providing better process stability and flexibility for improving each of the phases separately. The BTA system consists of the pulper to homogenize the waste, a plate screen below the hydropulper operated by an impeller to filter particles over 10 mm size. The moisture content of the influent is brought up to 75% before introducing it into the hydrolysis reactor the HRT of which is 4 days. The leachate obtained is introduced into the methanogenesis reactor which has a hydraulic retention time of 2 days. Gas lances within the anaerobic digester aid in mixing the digester contents so that maximized biogas yield is achieved by convection. At 37^{O}C a Retention Time of 14-16 days serves well for a Single Stage BTA process. For every milligram of organic waste 80 m^3 to 90 m^3 of biogas is produced containing 60% - 65% methane in single stage process while in the two stage process 110 m^3 -130 m^3 of biogas is produced per milligram of organic waste with 65% - 75% methane content. Multistage BTA system operates at an HRT of 2 - 4 days in the Hydrolysis phase and 3 days in the methanogenesis stage.

Various parameters influence the yield of biogas production of which maintenance of temperatures that would sustain the growth and multiplication of methane forming bacteria is one of them: mesophiles grow and are active in the 25 to 40^{o}C range while thermophiles operate within the 45-60^{o}C range while the psychrophilics operate below temperatures of 25^{o}C. It has been documented that methanogenic bacteria operating under mesophilic conditions are well active at 35^{o}C; however operating digesters at 37^{o}C temperature helps in quicker digestion of substrate [20].

Lotta Level *et. al*. [30] in 2007 analysed the structure of the microorganisms in two intermittently mixed reactors over an eight year period. The reactors were of 45 litre capacity

fed with organic household waste: one operated at 37 ^{o}C temperature with HRT of 30 days and an OLR of 3.0 g VS (L day)$^{-1}$ while the other was operated at 55 ^{o}C with 19 days HRT period and an OLR of 5.0 g VS (L day)$^{-1}$. The two processes were observed to be stable yielding 0.75 L (g VS)$^{-1}$ of gas with a methane content of 60%, and a reduction of Volatile Solids by 60% – 70%. The researchers observed that 34% of the microbial community under mesophilic conditions was occupied by Bacteroidetes while 27% were occupied by Chloroflexi at meophilic temperature. The majority of microbes belonged to the Thermotogae family (61%) in the case of thermophilic temperature. The Archaea community of microbes contained varied species at mesophilic temperature operations as opposed to that at thermophilic temperature operations.

Dhanalakshmi S.V *et. al*.[14] in 2014 demonstrated that anaerobic digestion of vegetable waste produced higher biogas yield of the order of 0.530 L gVS^{-1} at 35^{0}C while that at ambient conditions produced less than that obtained at 35 ^{0}C. The month of June recorded the highest yield of biogas that of the order of 0.809 L gVS^{-1} when the average temperature is 37^{0}C, followed by May when the biogas yield was 0.678 L gVS^{-1} and temperature recorded was around 38 ^{0}C and July recorded a biogas yield of 0.576 L gVS^{-1} at a temperature of 35.3^{0}C.

Maintenance of temperature at the desired point has been achieved by various methods like insulating digesters, heat exchangers, hot water jacket around the digesters, heating elements, steam injection within the digester [18] [44]. Documentation also supports the fact that if the temperature within the digesters drops below the desired range, it should be retained as quickly as possible to avoid hindrance to the digestion process [4].

Karthik Rajendran *et. al.* [38] in 2012 reviewed the various methods of maintaining temperatures within the digesters including solar heating, building underground digesters to maintain constancy in temperature, charcoal coating on top of the digester, placing paddy husk on top of the digester, solar pond water heater and insulating inner walls of the gas holder. The solar heating method suffered decreased efficiency during the winter months. The constant temperature maintenance in underground digesters was attributed to geothermal energy. The charcoal method increased digester temperature by 3^{0}C thereby increasing biogas production by 7-15%; the only drawback being the coating exercise

needed to be exercised every one and a half months. Other materials of insulating digester include expanded or extruded polystyrene, woolmesh, mineral wool, polyurethane foam, mineral fiber mesh, cotton, double digester wall, cork, saw dust, heat exchangers, hot water circulation of the fluid used in the cooling system of the generator via digester walls [34][17][19]or heat exchange between the exhaust gases released by the Internal Combustion engine – generator set and the digester contents to ensure year round electric power supply availability unaffected by the temperature and the weather conditions outside.

Mohammad, N *et. al.* in 1991 [34] stated that covering the French type biodigester treating MSW was unaffected by temperature drop when covered by a polythelyne. Anjan K. K *et. al.* [3] in 1988 documented that the plug flow digester remained less sensitive to temperature fluctuations as compared to the Janta type of biogas digesters. Hamad *et. al*.[25] in 1981 concluded the Chinese fixed dome digester to be having superior insulation properties as compared to the Indian counterpart where decrease in temperature was observed for a decrease in height.

Glass wool, Plaster of Paris, Saw Dust, Sodium Peroxide have been documented as insulation materials. Black cloth coating of digester and composites of glass wool showed temperature holding capacity for more than 70 hours while thermocol – sawdust mixture was able to perform the exercise for 36 hours successfully [33].

Agitating the system has been documented to increase the rate of biogas production. Records support the fact that electric biogas plants utilize 40% out of the 7-8% electric energy production during mixing of their digester contents. This necessitates the need to optimize mixing systems on energy front. Mixing helps avoid scum accumulation, aids in release of trapped biogas within the digester contents as well as reducing the hydraulic retention time and the Solid Retention Time of the digester substrates, helps in homogenizing the environment within the digester, avoids the formation of dead regions within the digester, helps increase the contact area of the substrate and the methane forming microbes thereby improving the yield of biogas. Kamarád *et. al.*[31] in 2013 established that unmixed digesters exhibit slow methanogenic activity as the toxic metabolites are inefficiently eliminated. To mix Low TS contents we require high speed agitators like the ones employing the propellers while on the

contrary slow paddle type mixing instruments serve well for the agitation of fibrous substrate that form scum/slurries containing over 9% TS[31].

Up to 70% of gas is released in intermittently mixed digesters during mixing process [17]. Lower Hydraulic and Solid Retention Time were recorded for mixed reactors as compared to the unmixed reactors. Low intensity mixing or uneven mixing or leaving the digester untouched is important so that microorganism growth and process stability is ensured. Passive mixing serves well for low Total Solids systems while Active mixing works well for high total solid systems [38].

ARTI Biogas systems claim to produce around 500 gram methane from 2 kg kitchen waste of organic kind as opposed to the requirement of 40 kg of cattle dung or sewage for the same amount of methane. Around 48 to 72 hours is taken for complete reaction to take place of the starchy eatable portion of the kitchen waste as compared to that of the conventional gobar plant which takes around 40 days. ARTI styled digesters are smaller of the order of 1-1.5 m^3 while that of the traditional gobar gas system is voluminous at around 4 m^3 being the standard size for household installations. The influent that goes into a gobar gas plant is 40 kg dung and 40 litres of water while that of waste is 1-1.5 kg kitchen waste and 15 litre water. The effluent is of the order of influent and is easier to handle in ARTI Biogas systems as compared to gobar gas plants [5].

The drawbacks suffered by ARTI Biogas systems are the large air gap between the gas holder and the digester that results in the 22% of the total digester area gas loss. The floor area occupied by a 1 m^3 plant is of the order of 2 m^2 and height occupied is 2 metres. Of the 1 m^3 volume the effective volume of the digester stands at 850 litres. 78% of the digester area is occupied by the gas holder tank with the usable gas volume at 400 litres. The HRT of ARTI Biogas system is 42.5 days that is designed to ensure optimum digestion of feedstock to biogas and compensate for incomplete mixing [43]. Relocating the filled digester is a difficult task and is energy consuming if contents are not emptied. This makes it difficult when one shifts his premises, has a transferable job, would like to move the digester in the sunny region to boast biogas production etc.

Implemenation of successful waste to energy system requires detailed conversion process study and accurate design engineering. Researchers have tried to design and evaluate

the economic feasibility of their waste to energy systems. S. J. Hernandez *et.al*[39]. designed a biogas system based on food waste of a restaurant in Mexico City to partially replace the requirement of LPG. The order of food waste produced is 40.5 kg per day containing 23% Total Solids. Total Volatile solids accounted for 94.2% of the Total Solids. Six cubic metres of digester volume was calculated for the specified data operating at 20^0C, 86 days of Hydraulic Retention Time with influent intake of 69.2 litres per day with 12.7% Total Volatile Solids. The 6 m^3 of digester volume was split into two parts: one was a 1 m^3 anaerobic digester continuously stirred and the other was a 5 m^3 anaerobic digester designed as per traditional style coupled to the first anaerobic digester. A saving of 692 kg every year of Liquid Petroleum Gas was obtained by the restaurant [42]. Though the detailing of the process flow methodology and economics has been well documented, the design of the proposed setup has not been covered. No control and instrumentation strategy has been incorporated and the drawings are limited to schematics only.

J.D Rozario *et al.*[28] prepared a model of a Hybrid Electric Power Generation System using Solar and Biogas for Housing Complex housing 30 apartment buildings; the cost effectiveness of which was tested in HOMER Software with a collective organic waste production of the order of 1050 kg with a theoretical biogas production of 210 m^3 by volume. With an operating efficiency of 83% four generators of 4.5 kW rating for continuous operation in synchronization with Photo Voltaic (PV) arrays were selected. Results obtained through HOMER Software highlighted lowest power generation cost of 0.242 dollars per kWh for the system of four biogas generator sets and one PV unit of 3 kW. With the decrease in the number of biogas generators and an increase in the number of PV arrays, the power generation cost increased [28]. The model has been analyzed thoroughly on the economic front, however no control instrumentation engineering and piping details have been provided in the plant layout.

The Project Report for the Biogas Power Plant and Organic Fertilizer Unit, Namakkal District, Tamil Nadu details available biomass resources, flow diagrams of process, technical data of the proposed units, equipments and accessories, layout of the plant and its economic feasibility [19]. The report though howsoever exhaustive, the design procedure and the underlying mathematics have been ignored.

Technical faults, operational difficulties and managerial deficiencies have resulted in failure of Biogas Power Plants [36] [29]. The priority thus lies in improvising upon the designs

for optimal biogas production, well controlled process and economically suitable configurations. Thus the need of a systematic design approach as a platform for building upon viable biogas to energy solutions that shall provide consistent and reliable energy all year round. This paper emphasizes on detailing the design engineering procedure and choosing the appropriate instruments for the development of a piping and instrument diagram for a 800kWh electric energy plant from organic fraction of Municipal Solid Waste with the goal of setting up a community based power plant for Sector 29 of Faridabad City, India with prime emphasis on compacting the plant size while adhering to system constraints and adopting the best possible solution to optimize biogas yield and energy production.

3. Description of topic:

Biogas Generation in India is haunted by the challenges of setting up biogas plants on a large scale, decentralized power systems that are economical, set up of profitable business via biomass power, overcoming the inadequacy and incapability of transportation, storage, and utilization of energy crops that are feedstock to the biogas plant [8]. The challenges faced on account of non- profitability, economical cooking gas availability, decentralized electric power generation - society based, residence based and institution based show promising future. Because of the rich energy and nutritional value of kitchen waste and its abundance as part of Municipal Solid Waste, it forms excellent biomass for biogas plants with added advantage of economical fuel, hassle free storage and easy transportation.

Microgrid, minigrid and ultimately the smartgrid all rely on the backbone of decentralized power generation of which renewable energy is the main player and biogas being the most reliable of them all because of the feedstock availability throughout the year. This potentially rich source of energy can be harnessed at the individual and community level provided we are able to increase the efficiency of every step of the process from intake of feed to the utilization of energy.

Biogas based power plants consist of a digester, a storage system, an H_2S Removal Unit and a water vapour removal unit (Fig.2). In addition to that a heat exchange system may be introduced to maintain the temperature at the operating point for constant biogas generation throughout the year. The sequence of the biogas storage unit, H_2S Removal Unit and water vapour removal unit may alter from design to design.

The first step in the entire process is preparation of the waste mix having proper C/N ratio. Softcomputing using Fuzzy Logic is proposed as a decision tool to replace the need of an expert guide in order to determine the worth of the prepared mix on a scale of 0 – 1 i.e. 0% to 100% based on the C/N ratio of the substrate and its methane yield potential in order to avoid the digester turning acidic or basic and hindering or lowering the methane generation process. No such attempt has been previously attempted and only manual C-N charts were used by experienced personnel for the said exercise. Input feed optimized on C/N ratio and methane yield will therefore be the initial area of address.

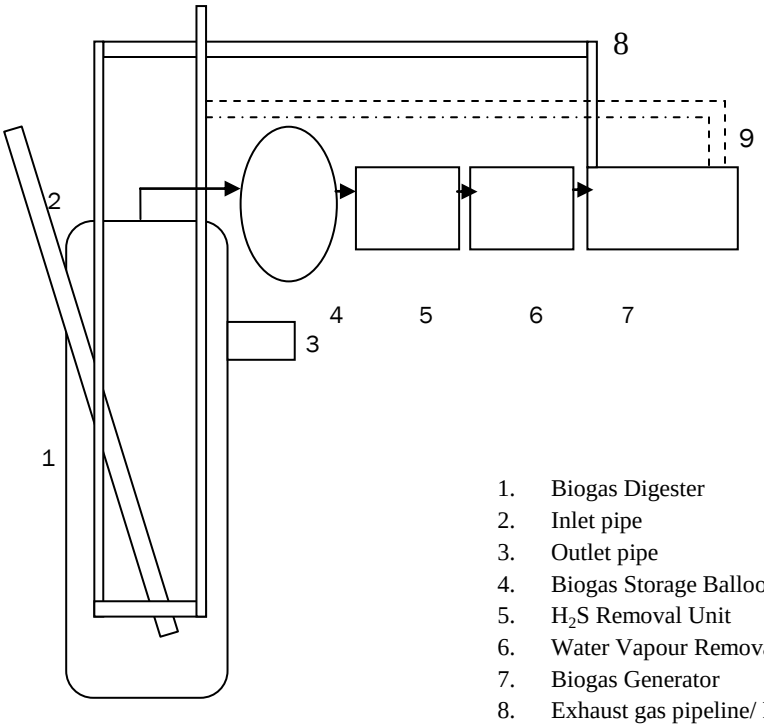
The second stage includes the feed digestion phase. A two stage process segregating the hydrolysis and the methanogenesis stage into two separate anaerobic digesters helps in achieving process stability and increased biogas and methane yield thus reducing the Hydraulic Retention Time which helps reduce digester volume making the system compact and feasible for installation in city or towns where space is a major constraint. Optimization of space usage by the system is thus the second area that will be addressed.

The third area that needs attention is that in biogas systems at individual level i.e. in systems of the order of $1m^3$ - $1.5m^3$ or even larger systems a guaranteed method of maintaining the temperature at its operating setpoint to provide stable environment to the methanogenic bacteria to function is by passing the exhaust gases from the Internal Combustion Engine - generator set or by heat exchange between the hot water from the cooling system of the generator and the digester contents. Charting of the time for which the exhaust gases from the IC engine need to be passed into the digester for maintaining mesophilic temperature i.e. 37^0C within it by mathematical analysis needs priority so that handy information is available for design, engineering and commissioning of heating systems and valve dynamics.

Small scale household type biogas digesters have no facility of a mixing system. Household scale biogas digesters as that provided by ARTI have a Hydraulic Retention Time of the order of 42.5 days due to incomplete mixing of digester contents. A dire need therefore exists to design an agitating system for this scale of biogas digesters. Agitating intermittently helps release biogas and boosts methane production; thereby reducing the Hydraulic and Solid retention time within the digester. A mobile biogas digester with rubber tubes wound around its periphery is proposed that would help in moving the digester around the space so that mixing can be accomplished as well as digester shifted to sunny places or other locations if need be.

A prototype of the above said mobile digester will be set up.

Finally after optimization of all the steps from feed intake to generation of electricity a comprehensive design of a 800kWh biogas power plant is proposed along with its control and piping diagrams, schematics and layout with economic analysis to determine the feasibility of the proposed design.



1. Biogas Digester
2. Inlet pipe
3. Outlet pipe
4. Biogas Storage Balloon
5. H_2S Removal Unit
6. Water Vapour Removal Unit
7. Biogas Generator
8. Exhaust gas pipeline/ Pipeline carrying hot water from generator cooling system to biogas digester with vent into the atmosphere if carrying exhaust gas
9. Return of water pipeline from digester into the generator cooling system

→ Arrow shows direction of flow of biogas from biogas anaerobic digester to storage balloon and finally to the generator via a H2S removal unit and Water Vapour Removal Unit.

Fig. 2: Schematic Diagram of a Biogas based power plant [32].

4. Objectives of Research

Problem statement formulation: Distributed Biogas based energy for cooking as well as for power generation using biogas as fuel obtained from organic fraction of kitchen waste is a rescue to the energy problems we face not only in India but worldwide. Gobar gas in Indian villages supplies the much needed cooking fuel; however the penetration of biogas plants into cities is too small due to space constraints and unavailability of cow dung. The anaerobic conversion of organic kitchen waste to energy finds its way into the terrace and verandah of individual households of small cities and towns. However their penetration into the balcony of apartments or smaller terraces and verandah of cities is small. A need exists to miniaturize the waste to energy systems for mass penetration into homes and communities for wider applicability of the clean biogas fuel obtained by anaerobic digestion for cooking and electric power supply on the primary front and scientific disposal of the organic part of Municipal Solid Waste on the secondary front.

Objectives of the research shall be:

- To maximize chances of proper feedstock preparation based on its C/N Ratio and methane potential using Fuzzy Logic Inference System of MATLAB.
- To mathematically evaluate the best possible system based on segregation of digestion phases and technology employed that will yield smallest possible digester volume.
- To develop charts of the time interval for which exhaust gases from IC engine need to be introduced into the digester for maintenance of set operating temperature (37^0C).
- To develop prototype of a biogas digester with mobility feature that will solve the purpose of agitation as well as digester relocation and determine its economic feasibility.
- To design a biogas based electric power system optimized on substrate C/N ratio and methane potential, space, methane/biogas output.
- To perform economic evaluation of the optimized biogas power plant designed.

5. Methodology to be adopted:

Development of Fuzzy Inference System: The methodology to be adopted consists of developing a Mamdani Style Fuzzy Inference system in MATLAB that would classify feedstock yielding methane over 55% under neutral pH conditions as selected for intake. C/N Ratio and Methane Potential of the feedstock would be assigned as input variables on which 'If–then' Rules would be applied; the output would be classified as either 'Accepted' or 'Rejected'.

Mathematical Evaluation of designs: For Optimization of space a comparison would be made on the volume of space reduction obtained for that of a two stage anaerobic system digester and a BTA technology style system implementation over a single stage digester system. The evaluation will be carried out mathematically on the basis of literature review.

Formula Derivation for temperature maintenance within digester: The steps followed would be to first calculate the power generated throughout the year for the city of Faridabad, Haryana, India. The average temperature of Faridabad City varies widely between 15^0C during winters to 40^0C during summers. The activity of methanogenic bacterium decreases with the decrease in temperature with every 10^0C drop in temperature reducing the biogas yield by 50% and a 39% drop in biogas generation for temperature drop from 20^0C to 30^0C. Power generation in the temperature ranges of 35^0C - 40^0C, 30^0C - 35^0C, 25^0C - 30^0C, 20^0C - 25^0C and below 20^0C would be calculated the percentage content of Total Solids, Volatile Solids, Input Biomass, digestion efficiency and biogas density. The time required to keep the exhaust valve open to allow the passage of gases into the boiler tubes that shall lead into the digester will be calculated by Thermal Conductivity of Boiler Tubes, Surface area of boiler tubes, specific heat capacity and mass of digester contents. Charts of the results will be made for handy information.

Developing Prototype for Agitation of Digester: A prototype will be developed to agitate the digester and provide it with mobility feature. The scope will be limited to home based biogas digesters. With the help of water tank and rubber tubes the prototype will be set for

implementation. A comparison between agitated and non-agitated system will be tabulated on the basis of empirical data obtained. The system will be evaluated for its economic worth.

Design, Layout, P & ID Diagrams: A detailed engineering drawing of the Biogas based power plant using all the units needed for practical 800 kWh unit will be designed. Based on results obtained from evaluation of best system on space front, the agitation system developed the heat exchange system for temperature maintenance, the H_2S Removal Unit and the Water vapour removal Unit would be designed. Specifications and the cost of the instruments and the equipments will be sought from vendors and a detailed layout and Piping and Instrumentation Diagram will be developed.

Economic Evaluation of the developed design: The design developed will be economically evaluated for its feasibility. The fixed costs, the recurring costs, the savings from electricity bill, the subsidies, the carbon credits will all be taken into account to calculate the return on investment and the breakeven point.

6. Proposed/expected outcome of the research:

The outcome of this research will be a compact and efficient Biogas based cooking system/power system design that shall be well suited to city structure and shall act as a dustbin for organic waste that is otherwise lying on roads posing a challenge to the Municipal Corporations to be disposed off.

A new dimension to agitating the digester without inserting any equipment into it will be invented that shall provide a breakthrough in adoption of biogas digesters as energy system in every household because of its contribution to reduction in digester volume and ease of mobility.

7. Proposed Time Frame (Gantt Chart)

	Time Frame	Jan-June			July - Dec			Jan - June			July - Dec			Jan-June			July-Dec			March		
		2015			2015			2016			2016			2017			2017			2018		
	Months →	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	37	38	39
	Course Work																					
ACTIVITY	Extensive Literature Search																					
	Problem Statement Formulation																					
	Development of Fuzzy Inference System for feedstock selection and paper publication																					
	Evaluation of various systems for compacting digester dimensions and paper publication																					
	Formulating time of exhaust gas passage through boiler tubes and paper publication																					
	Development of prototype with agitation system and complete patent application filing																					
	Design of biogas power system																					
	Economic feasibility study																					
	Detailed Report Writing and Submission																					

8. References:

[1] Abdallah, M , Fernandes, L, Warith, M A , Rendra, S 2009, 'A fuzzy logic model for biogas generation in bioreactor landfills', *Canadian Journal of Civil Engineering*,; DOI: 10.1139/L09-015

[2] Agrawal, M, Mittal, A 2011, 'Micro Grid Technological Activities Across The Globe : A Review', *IJRRAS*, vol. 7, no. 2, accessed 19 October 2017, <http://docplayer.net/44663102-Micro-grid-technological-activities-across-the-globe-a-review.html>

[3] Anjan, K.K 1988, 'Development and evaluation of a fixed dome plug flow anaerobic Digester', *Biomass*, *16*, p. 225–235

[4] Aquafix, 'Anaerobic Digester Upset & Troubleshooting', < https://teamaquafix.com/anaerobicdigester-upset-troubleshooting/>

[5] Arti Rural Technology Institute, 'Arti Biogas Plant : A compact digester for producing biogas from food waste', <http://www.pssurvival.com/PS/Biogas/Arti_Compact_Digester_For_ Producing_Biogas_From_Food_Waste_2010.PDF>

[6] Aydinol, F.T, Yetilmezsoy, K 2010, 'A fuzzy –logic-based model to predict biogas and methane production rates in a pilot–scale mesophilic UASB reactor treating molasses wastewater', *Journal of hazardous materials* , DOI:10.1016/j.jhazmat.2010.06.054

[7] Baskar, C , Baskar, S, Dhillon, R.S 2012, 'Biomass Conversion', *Springer*, p. 93 , accessed 20 October 2017 ,http://www.springer.com/in/book/9783642284175

[8] Biomass Knowledge Portal, 'Overview of biomass power sector in India', Ministry of New And Renewable Energy, < http://biomasspower.gov.in/About-us-3-Biomass%20Energy%20scenario-4.php>

[9] BTA International n.d. , *Mixing System for the Anaerobic Digestion*, 20 October 2017, < http://www.bta-international.de/en/der-bta-prozess/ schluesselkomponente/ mischsystem-fuer-die.html>

[10] Chaturvedi, P 1996, 'Sustainable Energy Supply in Asia', *Proceedings of the International Conference*, Asia Energy Vision 2020, vol.1, ISBN: 81-7022-631-7, p. 193

[11] Clark, W. G 2015, 'Let's Build a Global Power Grid', *IEEE Spectrum* <https://spectrum.ieee.org/energy/the-smarter-grid/lets-build-a-global-power-grid>

[12] Control Engineering Staff, 2009, 'Smart Grid Project Underway in Germany', *Control Engineering*, accessed 19 October 2017,<http://www.controleng.com/index.php?id =483&cHash=081010&tx_ttnews[tt_news]=7180>

[13] Deng, R, Yang, Z, Hou, F, Chow, M, Chen, J 2015, 'Distributed real-time demand response in multiseller–Cmultibuyer smart distribution grid', *Power & Energy Society General Meeting, IEEE*, ISSN: 1932-5517**,** DOI: 10.1109/PESGM.2015.7286260, accessed 19 October 2017, <http://ieeexplore.ieee.org/document/7286260/>

[14] Dhanalakshmi S V, Srinivasan S V 2014, 'Energy from Biomass – Comparison of biogas production at ambient temperature and at mesophilic temperature in semicontinuous anaerobic digester using vegetable market wastes',vol.6, no.1, *Applied Science Innovations Pvt. Ltd., India*, ISSN 0974 – 0546, p.349 – 355, accessed 20 October 2017, <http://www.applied-science-innovations.com/cst-web-site/CST-6-12014/CST%20-%2087.pdf>

[15] Dioha, I.J, Ikeme, CH, Nafi'u, T, Soba, NI, Yusuf, MBS 2013, 'Effect of Carbon to

Nitrogen Ratio on Biogas Production', *International Research Journal of Natural Sciences*, vol.1, no. 3, European Centre for Research Training and Development UK, <http://www.eajournals.org/wpcontent/uploads/EFFECT-OF-CARBON-TO-NITROGEN-RATIOON-BIOGAS-PRODUCTION.pdf>

[16] Distributed Generation Education Modules n.d., *Benefits of Distributed Generation*, accessed 20 October 2017 < http://www.dg.history.vt.edu/ch1/benefits.html>

[17] El-Bakhshwan, M.K.; S.M.A. Abd El-Ghafar; M.F Zayed and A.E. El-Shazly 2015, 'Effect Of Mechanical Stirring On Biogas Production Efficiency In Large Scale Digesters', *J.Soil Sci.and Agric. Eng*., vol. 6 , no.1, p. 47 - 63

[18] Energypedia 2016, *Digester Heating*, accessed 20 October 2017, <https://energypedia.info/wiki/Digester_Heating>

[19] EnviTec Biogas, 'Detailed Project Report for Biogas Power Plant + Organic Fertilizer Unit in Namakkal District, Tamil Nadu', <http://www.devalt.org/images/L2_ProjectPdfs/Detailed_project_report_for _biogas_power_plant.pdf>

[20] Goswami, R, Chattopadhyay, P, Shome, A, Banerjee, S.N, Chakraborty, A.K, Mathew, A.K, Chaudhury, S 2016, 'An overview of physico-chemical mechanisms of biogas production by microbial communities: a step towards sustainable waste management', *3 Biotech*, vol.6, no.1, DOI: 10.1007/s13205-016-0395-9, accessed 20 October 2017, <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4755961/>

[21] Government of India, Ministry of New and Renewable Energy Resources, "Solar/Green Cities," http://mnre.gov.in/schemes/decentralized-systems/solarcities/

[22] Government of India- Ministry of Power 2017, *Power Sector at a Glance*, accessed 20 October 2017, <http://powermin.nic.in/en/content/power-sector-glance-all-india>

[23] Gram Oorja 2017, *Our Projects*, accessed 19 October 2017, <http://www.gramoorja.in/microgrid-projects.html>

[24] Gupta, N, Jain, A 2011, *'* Smart Grids in India*', RE Feature*, Akshay Urja, MNRE vol. 5, no.1, accessed 19 October 2017, < http://mnre.gov.in/file-manager/akshay-urja/july-august-2011/EN/Smart%20Grid%20in%20India.pdf>

[25] Hamad, M.A.; Abdel Dayem, A.M.; El Halwagi, M.M **1981,** Evaluation of the performance of two rural biogas units of Indian and Chinese design. *Energy Agric.*, vol. 1, p. 235– 250

[26] India Smart Grid Knowledge Portal n.d., *Updates from the Smart Grid Pilot Sites***,** India Smart Grid Forum, accessed 19 October 2017, http://www.indiasmartgrid.org/pilot.php

[27] Jenkins, Nick, Long, Chao, Wu, Jianzhong 2015, 'An Overview of the Smart Grid in Great Britain', *Engineering*, vol. 1, no. 4, Elsevier, Science Direct , p. 413-421, accessed 19 October 2017,< https://doi.org/10.15302/J-ENG-2015112>

[28] Joan D'Rozario , Sabrina Shams, Shahinur Rahman , Ahmed Sharif , Enamul Basher, 'Cost effective Solar-Biogas Hybrid Power Generation System', *IEEE*, DOI: 10.1109/ICIT.2015.7125504, Electronic ISBN: 978-1-4799-7800-7, < http://ieeexplore.ieee.org/document/7125504/>

[29] Joshua ,S.K 2011 , 'A look at India's biogas energy development program – after three decades, is it useful (doing what it should) and should it be continued?', Master of Engineering and Public Policy – Inquiry School of Engineering Practice McMaster University.

[30] Leven, L, Eriksson, A, Schn´urer, A 2007, 'Efect of process temperature on bacterial and

archaeal communities in two methanogenic bioreactors treating organic household waste', *FEMS* , DOI:10.1111/j.1574-6941.2006.00263.x

[31] Luděk ,K, Stefan , P, Günther ,B, Michael, H, "Determination of mixing quality in biogas plant digesters using tracer tests and computational fluid dynamics," ACTA Universitatis Agriculturae Et Silviculturae Mendelianae Brunensis**,** Volume LXI 140 Number 5, 2013. [Online] Available: https://acta.mendelu.cz/61/5/1269/

[32] Majid, J, Rafi , K.M, Ahuja, N 2015, 'Customized Biogas Based Distributed Power Generation', *International Journal for Renewable Energy*, Print ISSN 2231-341, accessed 20 October 2017, <http://www.indianjournals.com/ijor.aspx?target =ijor:ijre&volume=2&issue=4&article=002>

[33] Mohan,S, Bindhu, B.K 2008 , 'Effect of phase separation on anaerobic digestion of kitchenwaste', *Journal of Environmental Engineering and Science*, vol.7, no.2, p. 91-103, 10.1139/S07-039 < http://www.nrcresearchpress.com/doi/abs/10.1139/S07-039>

[34] Mohammad, N 1991, 'Biogas plants construction technology for rural areas', *Bioresour. Technol. , 35*, p. 283–289

[35] Municipal Corporation Faridabad 2017, *Solid Waste Management* , accessed 20 October 2017, <https://www. mcfbd. com/solid-waste-management>

[36] Nirmalendunath, G 2015, "Implementation of decentralized power generation by biogas digester: Policy and perspective ," Carbon – Science and Technology, Applied Science Innovations Pvt. Ltd., India, Volume 7, Issue 2, pp. 53-65, 2015, ISSN 0974 – 0546, <http://www.applied- science-innovations.com/cst-web-site/CST-7-2-2015/CST-127.pdf>

[37] Patzwahl, S, Nacke, T, Frense, D, Beckmann, D, Kramer, K, Tobias T, Vollmer,G 2001, 'Microcontroller based Fuzzy System to optimize the anaerobic digestion in biogas reactors', *Proceedings of the International Conference, 7th Fuzzy Days on Computational Intelligence,* Theory and Applications, Springer- Verlag London, UK , ISBN:3-540-42732-5

[38] Rajendran, K, Aslanzadeh, S , Taherzadeh, M 2012, 'Household Biogas Digesters—A Review', *Energies*, vol.*5*,no.8,p.2911-2942,doi:10.3390/en5082911, <http://www.mdpi.com/1996-1073/5/8/2911/htm#B86-energies-05-02911>

[39] Sergio Juárez-Hernández, Alejandra Castro-González 2015, "Design and Economic Evaluation of a Prototype Biogas Plant Fed by Restaurant Food Waste," International Journal of Renewable Energy Research, Vol. 5, No 4 <http://www.ijrer.org/ijrer/index.php/ijrer/article/view/2823>

[40] Smart Grid Plus 2015, *Contact your National Contact Point*, ERA-Net, accessed 19 October 2017, < http://www.eranet- smartgridsplus.eu/contact/>

[41] Tembhurkar, A. R, Mhaisalkar, V. A 2008, 'Studies on Hydrolysis and acidogenesis of Kitchen waste in Two Phase Anaerobic Digestion', *Journal of the IPHE*, <http://re.indiaenvironmentportal.org.in/files/Kitchen%20waste.pdf>

[42] The Economic Times 2016, *States resolve to provide 24x7 power to everyone by March 2019*, accessed 20 October 2017, <http://economictimes.indiatimes.com/industry /energy/power/states-resolve-to-provide-24x7-power-to-everyone-bymarch 2019/articleshow/52802534.cms>

[43] Voegeli, Y, Lohri,C, Kassenga,G, Baier,U and Zurbrügg,C 2009 , 'Technical And Biological Performance Of The Arti Compact Biogas Plant For Kitchen Waste - Case Study From Tanzania' Proceedings Sardinia, Twelfth International Waste Management and Landfill Symposium ,<http://bioenergylists.org/files/arti_biogas.pdf>

[44] Waste Digester Design Instructor Materials, *Hand On Educational Activities From NSF Succeed Work*, <https://sites.google.com/a/ncsu.edu/civil-freshmanactivities/waste-digester-design/waste-digester-designinstructor-materials
[45] Wikipedia 2017, *Electricity sector in India*, accessed 20 October 2017, <https://en.wikipedia.org/wiki/Electricity_sector_in_India>
[46] Wood, E 2016, *India floats Plan to Install 10,000 Microgrids and Mini-Grids*, Microgrid Knowledge, accessed 19 October 2017, <https://microgridknowledge.com/microgrids-and-mini-grids/ >

synopsis

Submission date: 06-Nov-2017 11:21AM (UTC+0530)
Submission ID: 875068311
File name: 06neena1_synopsis.doc (390K)
Word count: 8634
Character count: 48738

synopsis

8%	5%	5%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

03.11.17

Vikram Kr. Sharma
University Librarian
Dr. O.P. Bhalla Central Library
Manav Rachna International University
Faridabad

1	Anuja, Neeraj Bansal, and Khwaja M. Rafi "Fuzzy computing for feedstock selection ... biogas plant", 2015 International Conference ... Soft Computing Techniques and Implementations (ICSCTI), 2015.	2%
2	...	2%
3	smartgrid.epri.com Internet Source	<1%
...	... "Effect of process temperature on ... biogenic bioreactors treating organic ... household waste", FEMS Microbiology Ecology,	<1%
...	...	<1%
...	...	<1%

		<1 %
7	www.sswm.info Internet Source	<1 %
8	www.ict4smartdg.eutc.org Internet Source	<1 %
9	"microgrids [guest editorial]", IEEE Power and Energy Magazine, 5/2008 Publication	<1 %
10	Submitted to University of Keele Student Paper	<1 %
11	Rajendran, Karthik; Aslanzadeh, Solmaz and Taherzadeh, Mohammad J.. "Household Biogas Digesters--A Review", Energies (19961073), 2012. Publication	<1 %
12	Demirer, G.N.. "Two-phase anaerobic digestion of unscreened dairy manure", Process Biochemistry, 200511 Publication	<1 %
13	Mohan, S. Bindhu, B.K.. "Effect of phase separation on anaerobic digestion of kitchen waste", Journal of Environmental Engineering and, March 2008 Issue Publication	<1 %
14	S.V. Kulkarni. "Optimal Sizing of Distributed Generation in a Micro Grid", 2006 IEE [illegible] Publication	<1 %

		<1%
15	catf.us	<1%
16	[illegible] Pramod Singh, and Pandurya [illegible] and its environmental [illegible]	
	[illegible]	<1%
18	Xuchuan Shi, Jia Lin, Jiane Zuo, Peng Li, Xiaoxia Li, Xianglin Guo. "Effects of free ammonia on volatile fatty acid accumulation and process performance in the anaerobic digestion of two typical bio-wastes", Journal of Environmental Sciences, 2017	<1%
19	biotechnologyforbiofuels.biomedcentral.com	<1%
20	www.science.gov	<1%

21	en.wikipedia.org Internet Source	<1 %
22	horizon.documentation.ird.fr Internet Source	<1 %
23	acta.mendelu.cz Internet Source	<1 %
24	www.dergipark.ulakbim.gov.tr Internet Source	<1 %
25	waset.org Internet Source	<1 %
26	www.osti.gov Internet Source	<1 %
27	Biogas Technology Transfer and Diffusion, 1986. Publication	<1 %
[illegible]	[illegible] Internet Source	<1 %
[illegible]	www.mdpi.com Internet Source	<1 %

Exclude quotes

Exclude matches

Exclude bibliography